Trace gas assimilation of Mars orbiter observations

Conference or Workshop Item

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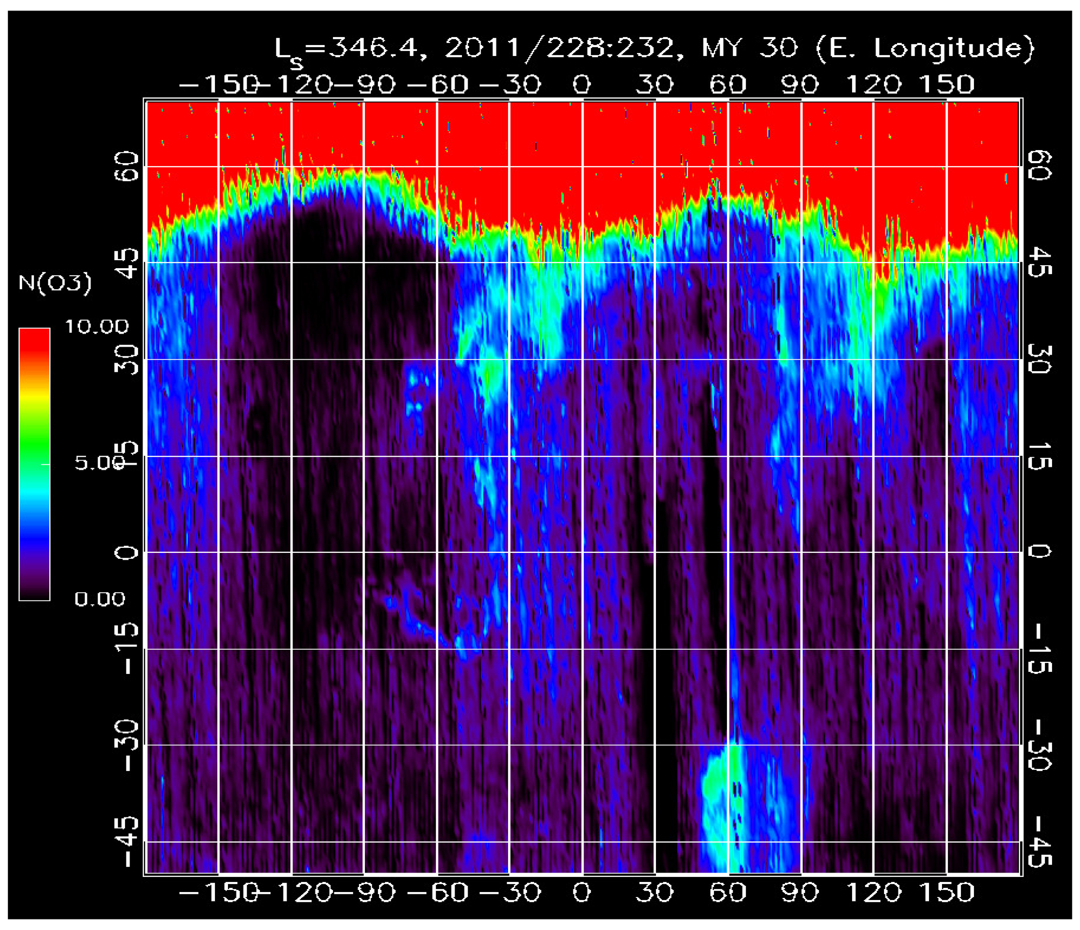
1. Introduction

- **Observations of trace gases are a key reference for chemical processes in the martian atmosphere**
- **Computer models can be used to explore their global temporal and spatial distribution**
- **Our project aims to assimilate trace gases into the LMD/UK MGCM to develop the representation of trace gas transport, sources and sinks in the model**

2. Observations



5 days worth of MARCI observations of column ozone abundance (R.T. Clancy, private comm. 2012)

Current observations of trace gases come primarily from 2 instruments:

- **TES** (Thermal Emission Spectrometer) providing water vapour column abundances (1999–2006)
- **MCS** (Mars Climate Sounder) and **MARCI** (Mars Color Imager) acquiring water ice optical depth and ozone column abundances respectively (2006–present)
- Observations are sparsely spread across the globe and limited to repeat observations at same local time due to spacecraft's orbit
- Mission to gain a clearer understanding of sources and sinks of trace gases have been proposed such as the **Exomars Trace Gas Orbiter**

3. Modelling trace gases

To model the spatial and temporal distribution of trace gases we use:

- The **LMD/UK MGCM** (Martian Global Circulation Model) [1] developed by a close collaboration of Laboratoire de Météorologie Dynamique, Instituto de Astrofísica de Andalucía, University of Oxford and the Open University with the LMD physics package
- The **LMD photochemical module** [2] containing 16 chemical species including ozone and methane

Specific to our UK version:

- A **spectral** dynamical core to solve fundamental laws of physics and fluid motion
- A **semi-lagrangian tracer advection scheme** [5] to provide realistic 3-D fields of trace gases
- The **Analysis Correction** (AC) scheme [3,4] for assimilation of observations

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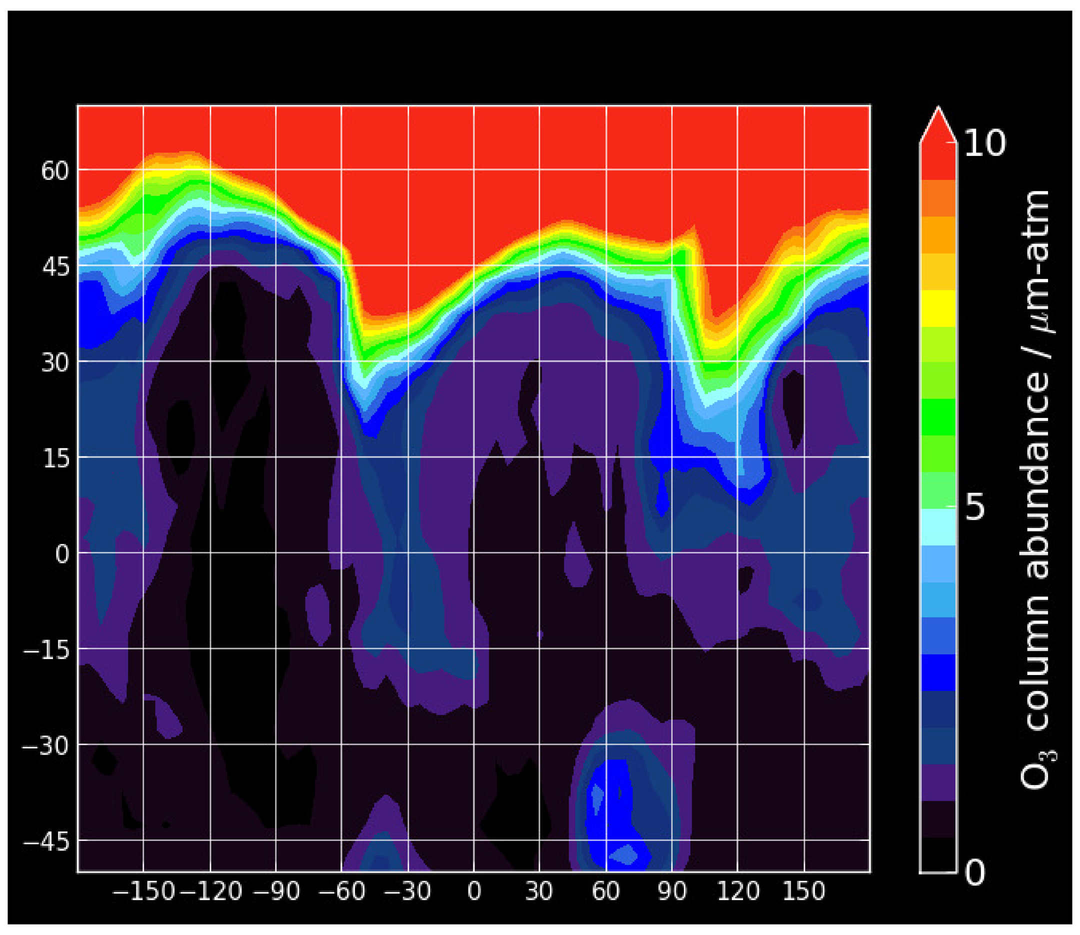
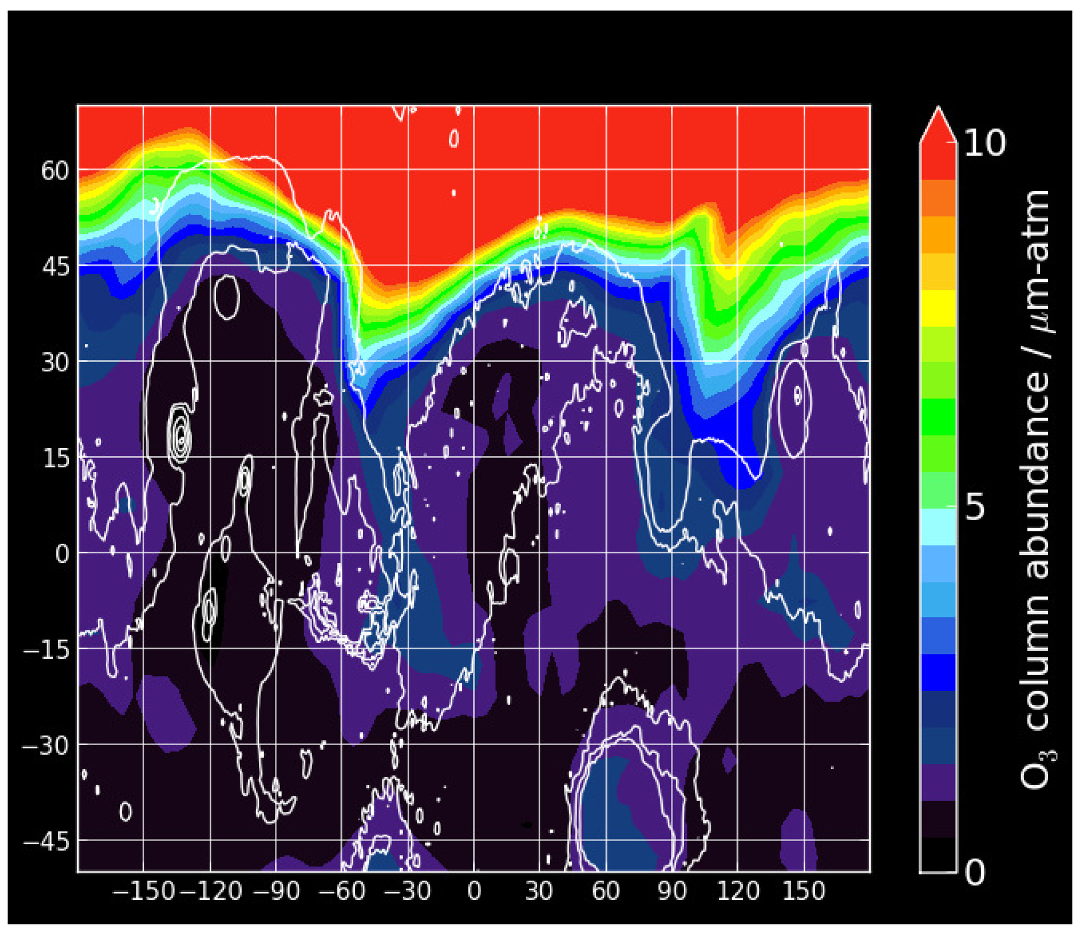
4. Ozone in our model

- Strong anti-correlation between ozone and water vapour evident in polar regions linked to HO_x radicals
- Comparisons at $L_s = 346.4°$ between a LMD/UK MGCM run and MARCI observations are very good, with clear features such as the Hellas basin and Elysium Mons visible
- Discrepancies do exist though, and these could be larger in other seasons



Ozone column abundance at $L_s = 346.4°$ from a model run at 32 levels, for comparison with MARCI observations (opposite)

5. Removing topographical effects



Normalised ozone column abundance at 610 Pa with a topography underlay

- Spatial distribution is largely characterised by the **topography** of Mars in northern winter
- **Wave-like activity** can be seen at the sharp gradients of ozone column abundance in the northern hemisphere
- After **normalising** ozone column abundance a similar pattern is seen indicating the variations across the globe are not an artefact of the topographical effects
- Models are important to use since they can 'fill in' gaps in observations
- However models are likely to have construction errors and include physical parameterisations, so an **optimal combination** of a model and observations is preferred

6. Assimilation of trace gas species

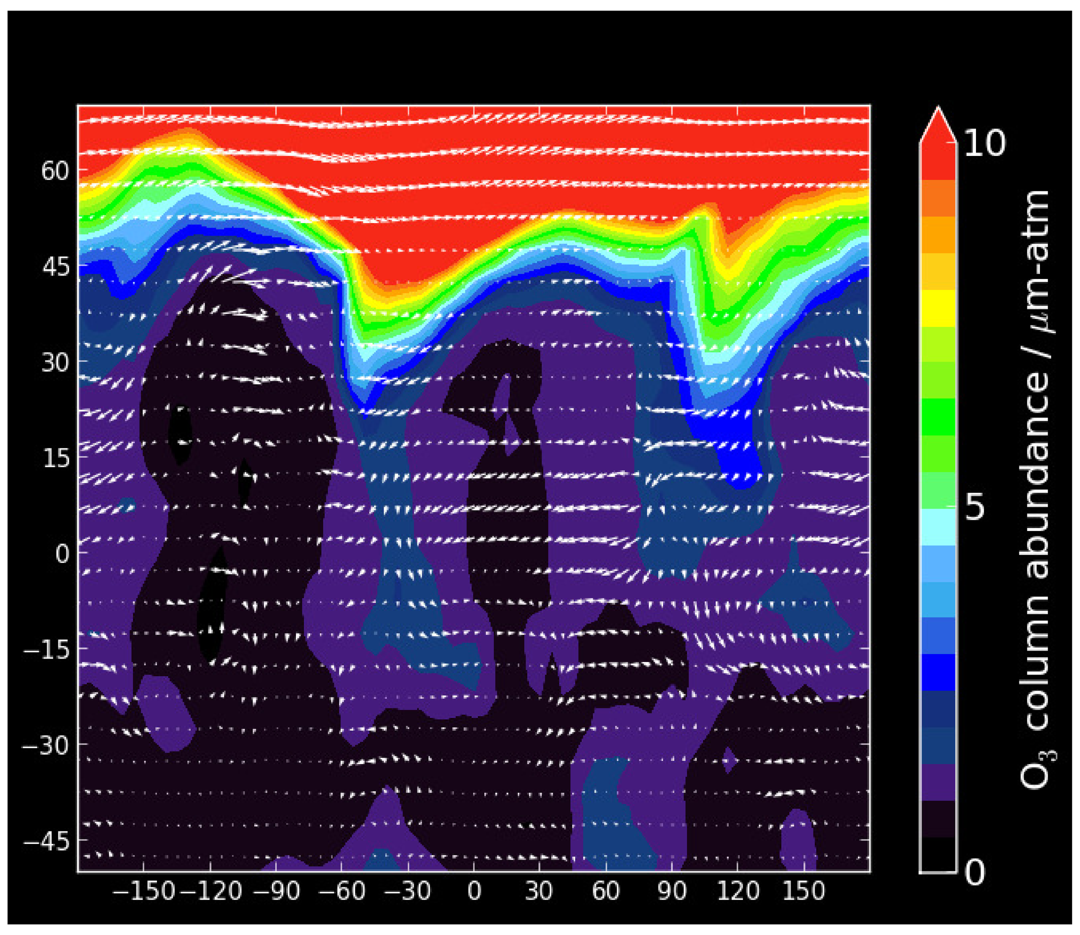
- Perform data assimilation using AC scheme [3,4], a sequential scheme adjusted to martian conditions
- **Temperature** and **dust optical depth** have been successfully assimilated and water vapour is currently in progress [6]
- Currently studying assimilation of artificial passive trace gas in preparation for assimilation of ozone observations
- **Ozone** is difficult to assimilate since it is a **reactive** tracer. Therefore ozone destruction and creation due to photochemical reactions need to be taken into account

Why do we want to assimilate trace gases?

- To study how accurately trace gases are modelled and identify sources and sinks
- To compare models against multiple observations over long time periods automatically, which is much less time consuming than manual comparisons

7. Near surface winds

- In northern winter the ozone is concentrated close to the surface
- **Advection** by near surface winds transports ozone-enriched air masses southward



Normalised ozone column abundance and near surface (1 km) winds as arrows averaged over the whole month

- Ozone abundance in **Hellas basin** is an area of interest for further study

8. Summary

- **Trace gases in the martian atmosphere can be represented using the LMD/UK MGCM which has full transport and photochemical capabilities**
- **A wealth of ozone column abundance observations over the global domain from MARCI can be inserted into the LMD/UK MGCM using the AC scheme to study the ozone cycle and identify sources and sinks**
- **Assimilation of ozone can potentially be used to study the dynamics of the atmosphere and the technique would also be useful for other trace gas species such as methane**

References

[1] Forget, F. et al., J. Geophys. Res., **104**, 24155, 1999 [2] Lefèvre, F. et al., J. Geophys. Res., **109**, E07004, 2004 [3] Lewis, S. R. and Read, P.L., Adv. Space Res., **16**, 9, 1995 [4] Lorenc, A. C., Bell, R. S. and MacPherson, B., Quart. J. R. Meteor. Soc., **117**, 59, 1991 [5] Newman, C. E. et al., J. Geophys. Res., **107**, 5123, 2002 [6] Steele, L. et al., EPSC-DPS Joint Meeting, 894, 2011